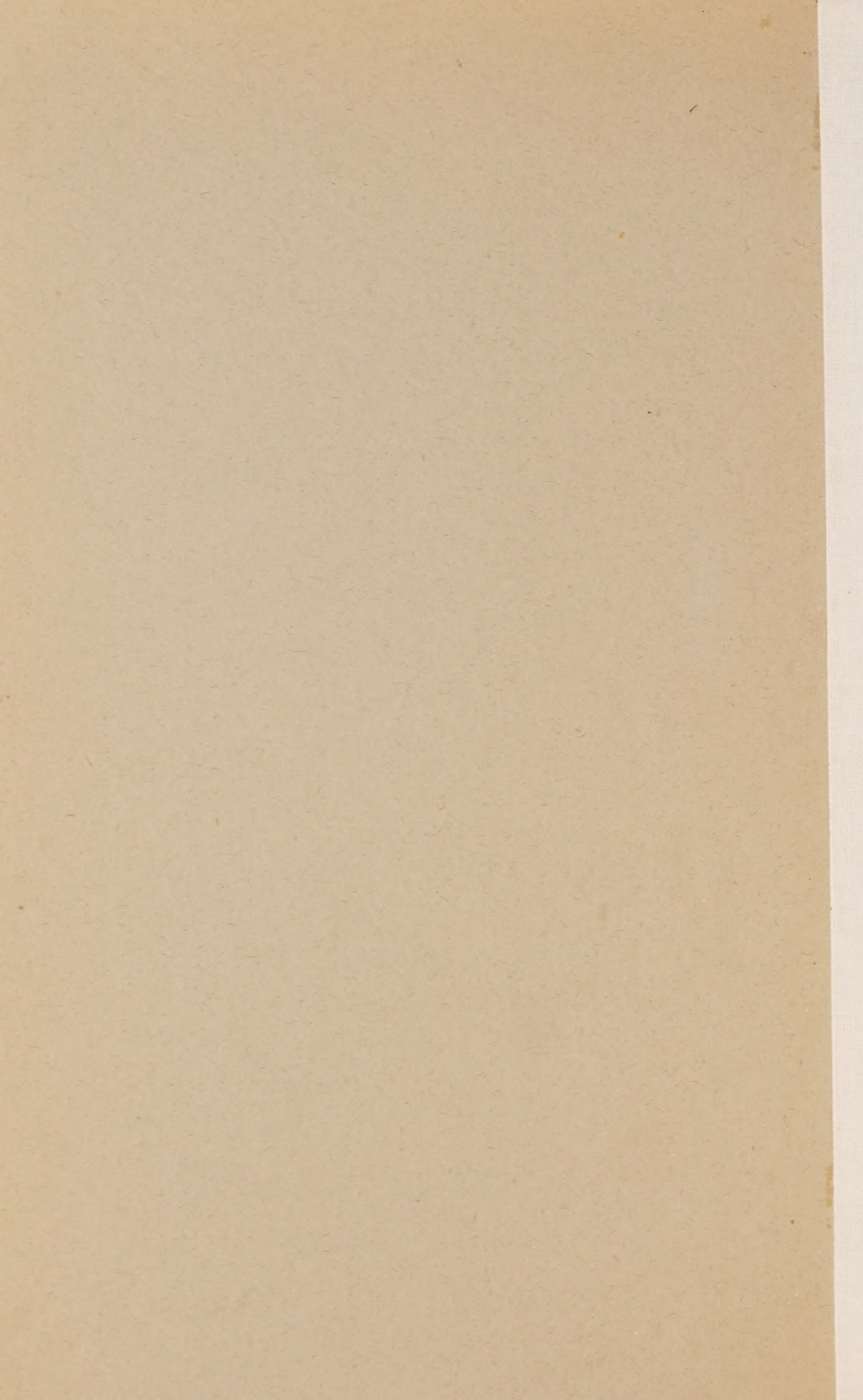


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# TENTH ANNUAL REPORT

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OF THE

## Commissioner of Highways

Ontario

1905

Part III—Bridge Construction

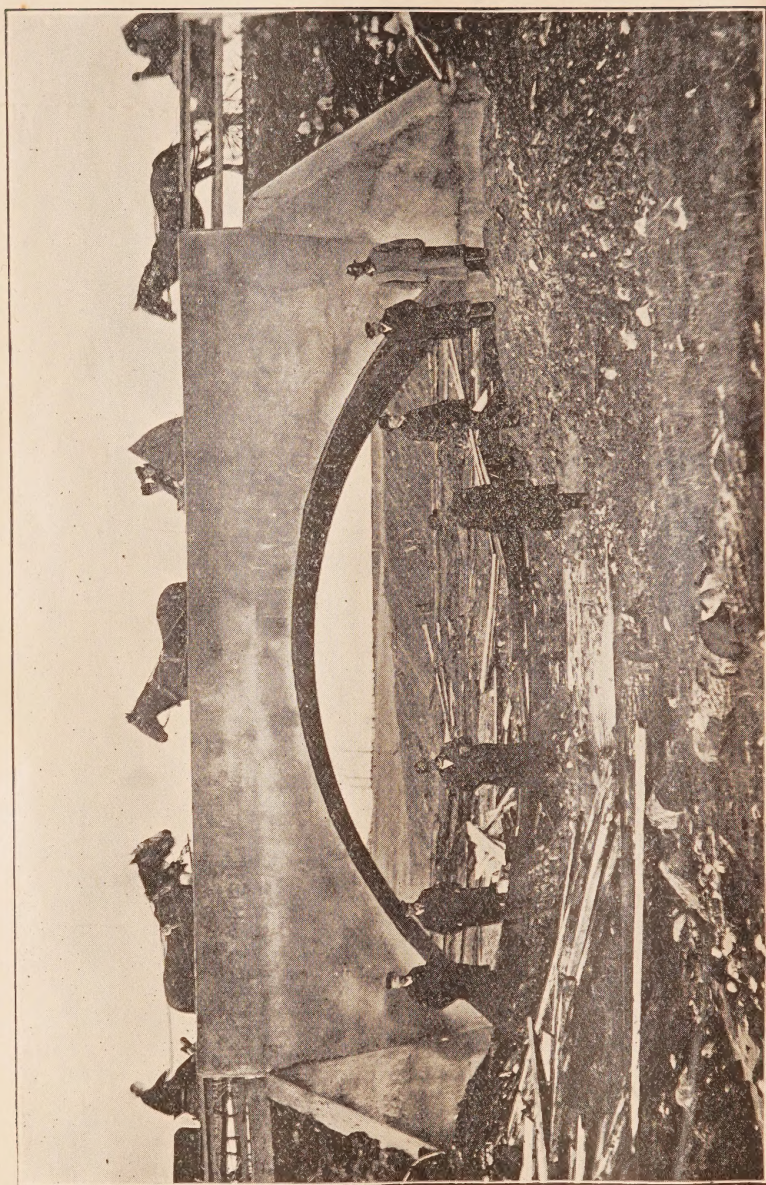
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1905 - Pt 3. Bridge Construction  
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TORONTO :

Printed by L. K. CAMERON, Printer to the King's Most Excellent Majesty  
1906.







CONCRETE ARCH, NEAR ARTHUR, WELLINGTON COUNTY, SPAN, 35 FEET; WIDTH OF ROADWAY, 14 FEET; HEIGHT OF  
OPENING, 12 FEET 6 INCHES; COST, \$1,900,

TENTH ANNUAL REPORT  
OF THE  
Commissioner of Highways  
Ontario  
1905

Part III—Bridge Construction

PRINTED BY ORDER OF  
THE LEGISLATIVE ASSEMBLY OF ONTARIO



TORONTO :  
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1906.

- Part I—County road systems.
- Part II—Township road management.
- Part III—Bridge construction.
- Part IV—Road construction.
- Part V—Town streets.

## CONTENTS

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	PAGE.
HIGHWAY BRIDGES.....	7
Durability.....	8
Steel Trusses.....	8
Awarding Contracts.....	10
Tenders.....	11
Appearance.....	12
Painting Steel Bridges.....	13
Concrete Flooring.....	13
Cost of Steel Bridges.....	15
CONCRETE BRIDGES.....	15
Length of Span.....	15
Steel Reinforcement.....	16
Area of Waterway.....	16
Cost.....	17
Designing Arches.....	17
Flat Top Bridges.....	18
CONCRETE ABUTMENTS:.....	18
CONCRETE.....	20
Gravel or Broken Stone.....	20
Proportioning Materials.....	20
Rubble Concrete.....	21
Wet or Dry Concrete.....	22
Clean Material.....	22
Mixing.....	23
Depositing Concrete.....	23
PORTLAND CEMENT.....	24
Specification for Portland Cement.....	25
Testing Portland Cement.....	26
SPECIFICATION FOR CONCRETE BRIDGES, ABUTMENTS AND PIERS.....	27
SPECIFICATION FOR STEEL HIGHWAY BRIDGES.....	33
SPECIFICATION FOR CONCRETE FLOORING.....	45

HON. J. O. REAUME,

*Minister of Public Works, Ontario.*

SIR,—I have the honour to submit to you Part III. of the annual report of the Highways Branch for the year 1905, with reference to bridge construction.

I have the honour to be

Sir,

Your obedient servant,

A. W. CAMPBELL

*Commissioner of Highways,*

## HIGHWAY BRIDGES.

Bridge construction has passed through numerous stages. One of the oldest types of permanent bridge is the stone arch, brought to great perfection by the ancient Romans. A number of these built in Europe centuries ago are yet standing. Stone arches are still being built, but stone is giving place to steel, cement-concrete, and concrete reinforced with steel. A little over a century ago, metal was first used in bridge building in England. Cast iron, and wrought iron have in turn held a prominent place, but these have been displaced by structural steel, the material that has made possible the sky-scraping office, mercantile and apartment buildings of the large cities.



STEEL BRIDGE IN ELGIN COUNTY.—SPAN, 145 FEET; WIDTH OF ROADWAY, 16 FEET; CONCRETE FLOOR, CONCRETE ABUTMENTS; COST OF ABUTMENTS, \$3,600; COST OF STEEL, \$5,240; COST OF CONCRETE FLOOR, \$423.36; GRADING, \$204.15; INSPECTION, \$70; TOTAL COST, \$9,547.57.

The principles of bridge design, whether in the case of wooden trusses, steel viaducts, stone or concrete arches, are more perfectly understood than they have ever previously been, and bridge structures in Canada are among some of the most noted the world has produced. The River St. Lawrence, the Niagara, and many chasms on the Canadian Pacific Railway in its route through the Rocky Mountains, are crossed by structures of great span and remarkable perfection. Notable among these will be the railway bridge across the River St. Lawrence, seven miles west of Quebec, from the Chaudiere on the south side, to Cap Rouge on the north. The main span is to be 90 feet longer than the central span in the Bridge of the Forth; and no other trussed span has reached half its length. Work was commenced on the substructure in the summer of 1900, and the superstructure will not be completed before the fall of 1908.

In Ontario, as with road building in the Province, bridge building had its commencement but little more than a century ago. What these early

bridges were there is little record, but it may be conjectured that they were of an exceedingly crude type. On the first roads opened, such as the Governor's Road, Yonge Street and the Kingston Road, large streams and rivers were forded. In other cases the first crossings doubtless consisted of a few roughly hewn logs thrown across the stream to accommodate the primitive traffic of that date.

### Durability.

While wooden truss bridges are being built to some extent in Ontario, yet the increasing price of timber and the inferior quality obtainable, is bringing into common use the more permanent materials, steel and concrete. Arches of concrete, or concrete reinforced with steel, are growing in favor for short highway spans up to fifty or sixty feet. Longer spans are being built with steel superstructure, concrete abutments, and concrete flooring. Timber for this purpose is temporary, the life of the ordinary wooden bridge rarely exceeding ten years. Formerly a much better class of timber could be had than is now obtainable. Repairs are needed every year, and the cost of these, in sending men and material for necessary details of maintenance, to put in a new stringer or post, etc., very soon runs up a bill equal to the original cost of the bridge. Steel bridges, it is true, require attention to maintenance in the matter of painting, tightening, putting in new rivets, but this can be done periodically and in a comprehensive manner, so that the cost of repair is not made up of time wasted in going to and from the work with men and material for trifling defects. By using steel stringers, concrete floors, and concrete abutments, a large measure of durability is attained.

The life of steel highway bridges has not yet been fully determined. Structural steel as now used is practically a new material. It is little more than five years since it has wholly superseded wrought iron. No structural steel highway bridges have been erected long enough to determine their life. In any event, the life is dependent upon the quality of the bridge. Light or otherwise inferior structures put up by incompetent makers, have failed within a year, or have required stiffening and strengthening. Municipalities cannot exercise too much good judgment in seeing that the steel bridges built by them are of sufficient strength, of good design, and properly finished and erected in matters of detail. Steel is more durable than iron. One of the oldest iron highway bridges in Ontario is a 150-foot span in Elgin County, built in 1878. While not as heavy as present practice requires, it is still in good condition after being in use twenty-eight years.

### Steel Trusses.

Steel bridges are of numerous types and classes; among others, suspension bridges, arch bridges, cantilever bridges, draw bridges, continuous bridges and simple beam bridges. In this classification, simple beam bridges include those in which the beams are made up of trussed members; so that beam bridges may be made of steel girders, or trusses in various designs, such as the Pratt, Warren, Petit, Bowstring and Baltimore. This refers to the superstructure only, which rests on a substructure of abutments, piers and foundations. The abutments are the end supports and the piers are intermediate. A bridge of a single span will have two abutments and no piers. A bridge of two spans will have two abutments and one pier. All these designs are good in a general way, but the choice of the most suitable type of bridge for a given location, the detailing of the design in all its parts, and the final erection of the bridge, call for the best engineering skill and experience.

The simplest form of a truss is a triangle; and a bridge truss, as ordinarily understood, is a framed structure made up of a series of triangles so connected as to act as a single rigid body. The sides of the triangles are stiff, straight members made up of single bars of steel, or various shapes riveted together. A panel of a bridge is the section between the joints of the lower chord.

A through bridge is one in which the floor is supported at or near the level of the lower chord; and in a deck bridge, the floor is supported at or near the level of the upper chord. The through bridge is the more common



HIGH TRUSS STEEL BRIDGE, YORK COUNTY.

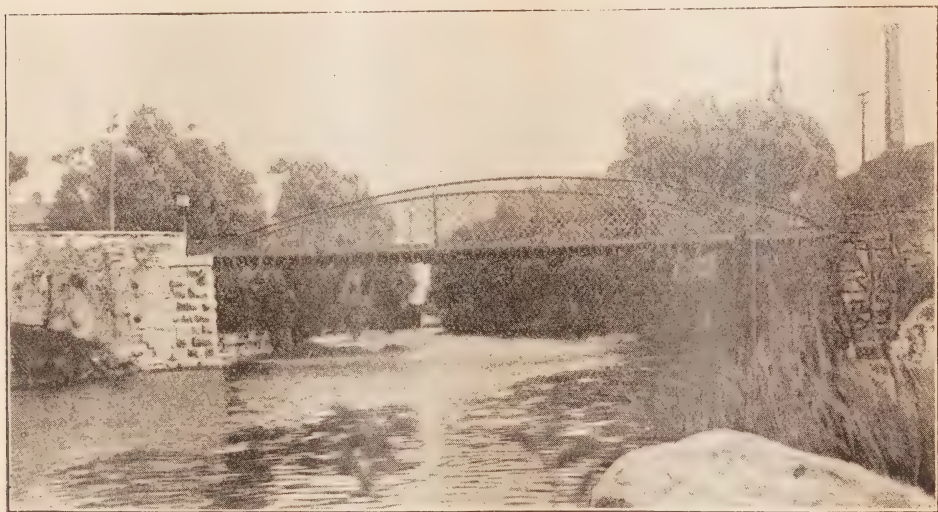
type. High truss bridges include through bridges which require an overhead system of lateral bracing; while low or pony trusses are not sufficiently high to require lateral bracing above the roadway. Low or pony trusses are used for short spans, and high trusses for longer spans.

Truss bridges are also classified in accordance with the manner in which the joints are connected. In the pin connected truss, the members are connected at each joint with a pin, resembling a large bolt, which fits closely into holes drilled through the ends of the members. In riveted bridges, all connections are riveted. Pin connected bridges are very easily erected, and are economical of material; but they vibrate readily, the joints are subject to considerable wear, and cannot be painted in such a manner as to protect them from rust; the members get loose and out of adjustment, and care is required to keep the bridge in order. A bridge with riveted connections is a stiff structure. The joints can be more perfectly protected from

rust and the bridge will stand more rough usage than will a pin-connected span. It is not so liable to accident from the failure of a single member, or from a concentrated load. Riveted connections should always be used for highway spans under 250 feet.

Trusses with riveted connections in most general use are the Warren with and without sub-verticals, the double intersection Warren, the Pratt, and the Baltimore. Pin spans are nearly always Pratt trusses with a single web system. Long spans usually have inclined top cords. In the majority of cases Pratt or double intersection Warren trusses are used for spans from 90 to 300 feet; and from 50 to 90 feet riveted Warren trusses. Pony trusses are suitable for spans of 30 to 70 feet; and rolled I-beams for spans up to 30 feet.

The steel work should be complete in itself, and not in any way dependent upon other materials. This principle is frequently violated by building up the ballast walls to carry the joists on the abutment, instead of putting



STEEL BRIDGE, GUELPH.—BOW-STRING TRUSS.

in end floor beams. With this construction it is impossible to have the end bottom laterals tight, as the action of the anchor bolts cannot be depended upon to take the stress. In short I-beam spans, each beam should be tied to the adjacent beams with  $\frac{3}{4}$ -inch tie rods spaced not over five feet apart. In other respects the principle should be followed, leading, in first class work, to steel joists, steel hand railings, and solid concrete floors.

The cost of steel bridges increases more rapidly than the length, owing to the heavier members required. For this reason, instead of a single long span, it is frequently advisable to build one or more piers and use shorter spans. This is a matter to be regulated by the relative cost of masonry and steel. An old rule which may serve as a general guide, requires the cost of the sub-structure to equal the cost of the superstructure in order that the whole may be a minimum.

#### Awarding Contracts.

Municipal councils when erecting steel bridges should secure competent engineering advice. The course pursued by some, indeed many municipali-

ties, has, however, resulted disastrously, and has in instances thrown steel into disrepute. Councils frequently advertise for tenders, and without any expert advice, award the contract.

It has been a not uncommon error that, with false ideas of economy, councils have accepted tenders for a steel bridge because of a saving of ten dollars in first cost, when the more expensive bridge was better value by hundreds of dollars. A poor steel bridge is dear at any price. Councillors cannot be expected to judge as to the qualities of a steel bridge as they can of timber, with which they are all familiar, and they are fully justified in obtaining proper engineering advice in the matter—in fact, a council is not justified in doing otherwise.

An engineer will be able to advise as to the proper form and material for abutments, often saving the amount of his fee in this respect alone, before touching the steel work. He will advise as to the dimensions and special requirements of the bridge to be erected. He will check over the plans when first submitted by the bridge companies, to decide as to the merits of the design and strength proposed. He will scrutinize the detail plans of the accepted tender and see that proper connections are adopted. The weak spot of many bridges is in the connections, and a bridge is no stronger than its weakest part. When the bridge is being erected, he can see that the specifications are being carried out. He can see that the members are properly assembled, each part being put into its proper position. A very common defect is the putting of parts end for end, and as a result other parts are twisted and distorted to get them together. Parts should be brought squarely together, giving a full bearing. Spaces should not be left, particularly in the covered parts, where water might find lodgment. Rivets should be examined to see that they are tightly driven, that none are distorted, and that there are no badly shaped or burnt heads. Many other details require the experience of a competent man with the training of an engineer, and councils which rely on anything else are not doing justice either to those they represent, or to their own reputation for good judgment.

### Tenders.

In asking for tenders there is certain information which should be given, in order that bridge companies may be in a position to prepare their estimates properly and on a uniform basis. The following particulars should be given as fully as possible:

(1) The specifications in accordance with which the bridge is to be erected. The "Specifications for Steel Highway Bridges" in this report may be quoted, if so desired.

(2) The length of bridge or of each span from centre to centre of bearings, or from face to face of abutments or piers.

(3) The clear width of roadway required.

(4) The live loads for which the trusses and flooring system are to be designed.

(5) The kind of floor to be used.

(6) The nearest railway stations, and length of haul to the site of the bridge.

(7) The character of the river bed, depth of water, speed of current, and height from the bed of the river to floor of the bridge.

(8) The style of bridge to be erected if there is any preference in respect of kind and height of trusses, riveted or pin connections.

- (9) If the bridge is skewed, the necessary angles should be given.
- (10) The number and size of piers if any.
- (11) Number and width of foot walks, and kind of hand rails.
- (12) When the work is to be completed.
- (13) Time to which tenders will be received, and to whom they must be addressed.

### Appearance.

While the large bridges excite our admiration, yet it is with the commoner bridge, everywhere spanning the smaller streams and rivulets on the King's highway, that municipal councils have most to do. A bridge is an important part of a landscape. It may, in its design and construction, harmonize with nature, or may lend a discordant note to a scene of beauty.

Very little consideration has been given to the artistic side of bridge construction by the municipal authorities having charge of the erection of bridges. It is taken for granted that questions of cost, economy, and utility are of too pressing a character in this new country, to permit any thought of the orna-



CAMEL-BACK TRUSS.—YORK COUNTY.

mental. It is fortunate, therefore, that good design and good construction possess in themselves, the chief elements of beauty, so that the results have been, on the whole, fairly harmonious. Nothing will accord with the ordinary landscape more perfectly than a well built arch of stone masonry, however simple in design. Arches of concrete on the highway are very much of the same class. A well built bridge, composed of stone or concrete abutments with steel superstructure, may also accord with a landscape without especial consideration having been given to its ornamentation. Much could be gained if more attention were paid to the appearance of these structures, but it is very easy to run to the opposite extreme with tawdry results. It is a short step from ornamental construction to constructed ornamentation,—the latter a very unsatisfactory substitute for severe simplicity.

In building bridges of steel and concrete, it should be remembered that they will last for many years, and their appearance is therefore a matter de-

serving much consideration. Concrete is a material which lends itself to easy manipulation, and much can be done by moulding it into graceful outlines. In doing this there should be no attempt at imitating other materials. The imitation of rock-faced stone so often seen in concrete blocks is extremely crude. Fussy ornamentation should be avoided. Concrete lends itself to distinctive and original treatment in the direction of panelings, mouldings, and graceful outlines, based on proper methods of construction.

### Painting Steel Bridges.

It is essential to the preservation of steel bridges that they be kept properly painted. Railway bridges are greatly injured by the vibration caused by heavy moving loads. But in the case of highway bridges, rust is the chief destructive agency. If they could be fully protected from rust, steel highway bridges would practically last forever. It is found that painting is required about once in five years; oftener if the bridge is in a much exposed situation by a lake shore.

Before painting steel, the surface should be absolutely free from rust, scale, moisture and grease. Rust is removed by scraping with steel scrapers; and scale, by the use of stiff wire brushes. Rust left beneath the paint will spread, in time the paint will flake off, and the metal is then wholly exposed to the destroying action of air and moisture. As portions of the metal in a bridge are only  $\frac{1}{4}$  and  $\frac{5}{16}$  of an inch thick, it is evident that rust, acting on both sides, can greatly weaken the structure. Connections, too, require special care, to see that they are fully protected. Bridge companies rarely exercise sufficient care, when erecting a bridge, to see that the scale is fully removed and the bridge properly painted.

The materials commonly used in painting bridges are red lead mixed with linseed oil; and oxide of iron, with linseed oil. The former is much the more desirable paint. These are subject to much adulteration and care has to be exercised to procure reliable materials. Lamp-black added to red lead, will change the color to a rich chocolate, and will not injure the paint.

### Concrete Flooring.

Bridge floors of plank usually wear out in from two to four years, and are a constant matter of expense for renewal or repair. With the increasing price of lumber, and the inferior quality now obtainable, it is only a matter of time until all bridge floors must be made of concrete. All steel bridges now being built should have concrete floors, or should at least be made strong enough to do so. When erecting a bridge it is much cheaper and more satisfactory to provide for this additional weight, than to reinforce the bridge afterwards.

Concrete adds a considerable load to the dead weight of the bridge, but this is more than compensated for by the extent to which it distributes the live load. With a plank floor, the weight of every vehicle passing over it is transmitted to the individual members of the bridge, causing a constant jarring and distortion that is very destructive to steel. With concrete, on the other hand, the weight of a passing vehicle is spread over a greater area of the bridge structure, the floor being a monolith and distributing the live load over a much greater bearing than can each plank. In this way the injury to bridges is much less with a concrete than with a plank floor.

So much is this the case that, with a concrete floor, it is not necessary to restrict the speed of vehicles travelling over it. With a plank floor it is always

expected that horses will not be driven over the bridge faster than a walk. But with concrete floors, travel is not interfered with, and horses may be driven at any pace.

Concrete floors cost more than plank, and add to the cost of the bridge by requiring greater strength to carry the additional dead load, but they will, in a term of years, be found a matter of economy. Concrete floors which have been in use for a number of years show practically no sign of wear, and if properly made, they should last as long as the steel work. As ordinarily constructed, concrete floors, exclusive of the steel stringers, are being laid for twenty-eight cents a square foot.

A concrete floor is practically a single slab of artificial stone laid over the bridge, but is, of course, constructed in place. It is usually six inches in the centre of the roadway and four or five at the sides. The timbers of the old bridge are frequently used for making the falsework. This falsework need



LIGHT STEEL BRIDGE ON STONE ABUTMENTS.

not be close-jointed; but if not, should be covered with tar paper, to keep the bottom of the floor smooth and prevent the concrete dropping through the crevices. The concrete is usually made of gravel, but cinders have been used. Cinder concrete, while not so strong, is not so heavy as gravel. The gravel used below the surface coating, may vary in size up to  $1\frac{1}{2}$  inches diameter. For the surface, there should be a one-inch coating of cement mortar or cement mortar with crushed granite. Or it may be surfaced with paving brick.

The bottom of the floor must be reinforced with steel to take up the tensile stress; also the top of the floor immediately over the stringers. Woven fence wire in several layers, and expanded metal are commonly used for this purpose. Round steel bars across the top of the stringers, with the ends of the bars bent over the flanges is an efficient form of reinforcement.

In advertising for tenders, a separate price for concrete should be asked as a number of bridge companies will not do this work, and it is not in the interest of the municipality to void or prejudice their tender for this reason.

### Cost of Steel Bridges.

The cost of steel bridges varies considerably. Every bridge demands a special estimate in accordance with a number of conditions, among which are: The price of raw materials; the type and dimensions of bridge to be erected; the loading which the bridge is designed to carry; the kind of floor to be used, whether timber or concrete; the cost of erection as affected by the character of river bed, depth of water, height of bridge above the bed of the stream and kind of foundations; the freight charges from the works, and cost of haulage from railway station to the site of the bridge; season of the year the bridge is to be erected, and length of time allowed for completion.

The following schedule, based on recent prices, will indicate the cost in a general way, but the conditions above enumerated will cause more or less difference in all cases, at times amounting to several hundred dollars, for a bridge properly built and adapted to the location. The prices are for steel alone, erected, and having strength to carry (but not including the cost of) a concrete floor. A concrete floor will cost, in addition, about 28 cents a square foot.

Length of Span.	Width of Roadway.			
	12 feet.	14 feet.	16 feet.	18 feet.
	\$	\$	\$	\$
30 feet.....	350	400	450	.....
40 ".....	500	550	600	.....
50 ".....	600	675	750	.....
60 ".....	775	875	1,025	.....
70 ".....	1,000	1,125	1,250	.....
80 ".....	1,200	1,300	1,475	.....
90 ".....	1,325	1,450	1,600	.....
100 ".....	1,500	1,775	1,950	2,150
110 ".....	.....	2,050	2,250	2,450
120 ".....	.....	2,300	2,575	2,850
130 ".....	.....	2,700	3,025	3,400
140 ".....	.....	3,275	3,500	4,000
150 ".....	.....	3,625	3,800	4,250
160 ".....	.....	4,500	4,350	4,650
180 ".....	.....	.....	5,800	6,100
200 ".....	.....	.....	7,250	7,550

### CONCRETE BRIDGES.

Concrete has for a number of years been very largely advocated for culverts, and has been used with undoubted success. The difference between a culvert and a bridge is merely one of size, and there is not a clear line of distinction. A culvert may be a small bridge; or a small bridge may frequently be referred to as a culvert. The use of concrete, however, has rapidly extended beyond the culvert stage, and concrete bridges may be definitely considered.

#### Length of Span.

Bridges of concrete may be of any span to which the stone arch was adapted. The largest stone arch ever built was one constructed over the River Adda at Trezzo, about the year 1380. It had a span of 231 feet at low water. The longest one in existence at the present time is the Cabin John bridge and aqueduct over Rock Creek at Washington, D.C. This has a span of 220 feet, a rise of 57 feet, while the roadway, 20 feet wide, is 101 feet above the stream. The arch ring is of granite, 6 feet deep at the crown.

There is no structural reason why concrete arches cannot be built to any span. The limiting factor is principally the cost, and that is decreasing from year to year, with the better understanding of concrete, and the lessening cost of the manufacture of Portland cement. At the present time small concrete arches of thirty, forty and fifty feet span are competing successfully with steel bridges. The cost of concrete arches is, as a rule, somewhat greater than for steel with concrete abutments, but the durability is very much greater. Numerous small concrete arch bridges have been erected in the counties of Oxford, Middlesex, Wellington, and other of the western counties. During the past season arches of twenty-five and thirty-five feet span were built in Simcoe and Wellington on the county road systems.



CONCRETE ARCH, SIMCOE COUNTY.—IN PROCESS OF CONSTRUCTION ; SEMI-CIRCULAR ; SPAN, 25 FEET.

### Steel Reinforcement.

Concrete has very great compressive strength but has little tensile strength. To reduce the quantity of concrete otherwise required to avoid tensile strains, concrete structures are now being reinforced with steel at points subjected to tensile stress. For this purpose steel wire, square and round steel bars, steel I-beams, expanded metal, corrugated steel bars, and other forms of metal are employed. In the case of an arch, the principal reinforcement is placed close to the interior face of the arch below the crown; and also on the back of the arch, at the haunches. These are the points where occur the chief tensile strains—where cracks open, in case of failure. For the same reason, wire netting, steel bars, etc., are used to reinforce concrete bridge-floors, the metal being placed very close to the bottom of the slab, where the cracks, under pressure, would open; and close to the top over stringers.

### Area of Waterway.

Concrete or other durable culvert tile are to be recommended for small waterways, where there can be no doubt as to their sufficiency to accommodate

the maximum flow of water. A difficulty with tile, however, has been that they are frequently used in places where a larger waterway should be provided; and while they may be large enough for the greatest flow of water for a period of years, yet there is apt to come a time of sudden flood or freshet when they are subjected to a rush of water for which they have not capacity, and a washout results.

For this reason, when putting in culverts which it is desired shall be permanent, care should be taken to provide a waterway of ample size for the unusual, not the usual, amount of flow. To this end, arch culverts of concrete or stone masonry should be employed, or concrete culverts with a flat top may be used for the smaller waterways. Concrete is not only cheaper, but is more durable than stone masonry.

#### Cost.

The cost of a concrete culvert will range from about \$4.50 to \$6.50 per cubic yard of concrete in the structure. The variation is created by a number of details—the availability of gravel, the cost of Portland cement, the cost of labor, and other items. The first to be constructed by a municipality always costs more than subsequent work.

#### Designing Arches.

A stone arch is so designed that the stone will remain in place without being held together by mortar. Concrete arches, on the other hand, are de-



STONE BRIDGE IN PAKENHAM TOWNSHIP.

pendent upon the cohesive strength of the materials. Good workmanship and good materials are therefore of exceedingly great importance in building concrete arch culverts. It is also essential that the side walls of arch culverts shall rest on a firm stratum of hardpan, gravel, compact earth, or other unyielding base, so that there will be the least possible settlement. If settle-

ment occurs to any extent it is rarely uniform, and the arch is thereby distorted and cracked. Usually it is necessary to excavate, for the side walls, a depth of about two feet below the bed of the stream. A certain depth is necessary in any location in order that the side walls may not only be safe from settlement, but also from the undermining tendency of the stream.

Arches or flat-top culverts may be made with or without a floor. If a floor is used, with steel rods through it acting as ties to connect the side walls, it will act as a broad support to the culvert, and the abutments need not be carried to so great a depth.

The amount of steel reinforcement necessary, and the design and curvature of the arch or bridge, requires careful calculation by a civil engineer in each case, if the best results are to be reached, although standard plans may be used with good results. An exact semi-circle is one of the strongest forms that can be used, but very frequently there is not sufficient head room, and a flatter design is necessary to give the required waterway. A segment of a circle is often employed, or an elliptical arch. The former, however, is too flat at the sides, and the ellipse too flat at the crown. A curve plotted midway between the segment and the ellipse more nearly meets desired conditions. Three and five-centred arches also provide for strength combined with less height than is required by a semi-circle.

#### Flat Top Bridges.

Instead of an arch, a flat top is favored by many engineers. It is more easily designed and constructed, provides a good waterway, and settlement of the abutments is not so injurious as to an arch. With skilful design, and good workmanship, however, an equal water area can be provided by an arch, with less concrete and less steel reinforcement, as an arch is stronger and will support more weight than will a flat cover or floor. Either an arch or a flat top may have a covering of loose gravel or broken stone, making it continuous with the roadway.

Concrete bridges with flat or square tops may be readily used up to spans of 40 feet. They consist of abutments or side walls, with a flooring of concrete reinforced with steel. Up to four feet, a reinforcement is not necessary. For spans from four to ten feet, the strength of the cover stone should be increased by means of smooth or barbed wire, wire netting, or other light reinforcement, fully imbedded in the concrete, but as close as possible to the bottom. Over ten feet, steel rods, and steel I-beams, may be used; or concrete beams reinforced with steel rods may be designed in such a manner as to lessen the cost of steel reinforcement.

In this class of construction, where steel I-beams are used, it is common practice to place the concrete on the top flange, leaving the web and lower flange exposed. Concrete is a complete preventive to rust, and to avoid the necessity of painting the steel from time to time, and to render the work absolutely permanent, it is desirable that the work be so designed as to fully encase the steel with concrete.

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#### CONCRETE ABUTMENTS.

Concrete has practically displaced stone masonry in the construction of bridge abutments. This material is quite as durable as stone masonry, requires less attention to repair, and is less liable to injury if undermined by the wash of a running stream.

Abutments built of concrete may be made of a mixture of Portland cement and gravel; or a mixture of cement, sand and broken stone. In either case,

the interior may be filled with large rubble stone, the work being carried on in such a manner that a casing of fine concrete will surround the rubble, and fill all voids between the larger stones.

The bridge seat should in design be adapted to the type of bridge to be erected, and should be finished with fine concrete. For truss bridges up to 75 feet span, there should be a top width of about three feet. The remainder of the abutment, if designed as a retaining wall, may have a thickness down to the footing courses equal to  $\frac{2}{3}$  of the depth below grade, the width increasing at the back of the abutment, and the face being vertical.

A bottom footing, about two feet thick and projecting about twelve inches, should form a base for the abutment. Care should always be taken to commence the abutment on a firm, unyielding stratum of earth, but ordinarily this can be secured by excavating about two feet below the bed of the stream.

Wing walls should be built as the situation may require, to protect the bridge and embankment from the flow of water. The top width of a wing should ordinarily be eighteen inches or two feet wide, and carried down with



CONCRETE ARCH, NEAR GLEN HURON, SIMCOE COUNTY.—SPAN, 35 FEET; COST, \$1,114.

a batter at the back to a footing of the same width as the abutment. By having the batter in this way, the earth rests on the abutments, and rises and settles more readily when acted upon by frost.

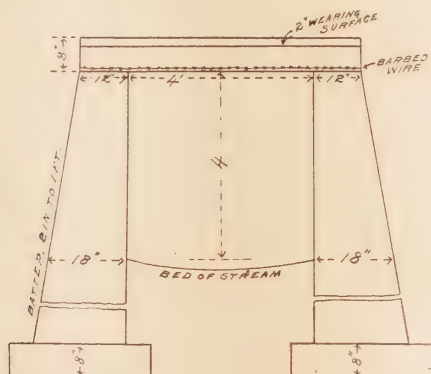
An abutment, in addition to supporting the bridge, must retain or keep in place, the earth filling behind it, so that there is a tendency to push it outward and overturn it on its footing. The undermining action of the stream has also to be guarded against. As the work is carried upwards, the back filling should be put in place and consolidated. If the earth foundation of the abutment is not secure, and unequal settlement or scour of the stream is possible, the bottom should be strengthened with piles driven at  $2\frac{1}{2}$  feet centres, the tops cut level, and the spaces filled with broken stone. The heads of the piles should be covered with a timber or concrete platform upon which to build the abutment. All timber should be kept below the water-line to prevent decay.

## CONCRETE.

Concrete may be regarded as an artificial stone made by a mixture of mortar and broken stone: the mortar being formed from a mixture of sand, Portland cement and water. Concrete is one of the most important and valuable materials of modern construction. The facility with which it can be moulded makes it suitable for a great variety of uses. It is, when properly made, of good materials, more durable than stone masonry, and costs less. While costing a little more than timber for abutments and culverts, it is so much more durable that, after a term of years, it is the cheaper of the two. In road and street works it is used for concrete tile, bridge abutments, arches and short span bridges and culverts, bridge floors, foundation for pavements, curbs and gutters, sidewalks, retaining walls, and other purposes.

### Gravel or Broken Stone.

In place of using cement, sand and broken stone, concrete may be made by mixing cement and gravel, as suitable gravel for this purpose, is itself a mixture of sand and small stones. The most suitable gravel for concrete is one which is a close, compact and uniform mixture of sand and pebbles, varying from very fine to coarse, so that there is the least possible percentage of voids in the mass. There is some difference of opinion as to the relative strengths of gravel and broken stone in concrete. The natural inference is that a rough, irregular surface will secure greater adhesion than one that is smooth. However that may be, there is little reason to doubt that gravel if properly used will make a good concrete.



### Proportioning the Materials.

The proportions of Portland cement, sand and broken stone (or Portland cement and gravel) to be used in mixing concrete, vary for different classes of work. They vary also according to the quality of sand, gravel, and broken stone. It is recognized that the greatest strength in concrete can be obtained by making the mortar rich in cement, rather than by lessening the quantity of stone. But beyond providing for a strong adhesion of mortar and stone, little is gained by making the mortar stronger than the stone.

An ideal concrete is one in which voids in the broken stone, and in the sand, are reduced to a minimum, by a mixture so graded from coarse to fine, that the interstices between the largest stones are filled by a smaller size, and so on, to the finest particles of sand and cement. Such a concrete, if it could be obtained, would be solid, waterproof, and without vacuum. Thus,



### Wet or Dry Concrete.

The amount of water to be used in mixing concrete is a subject of some controversy, some engineers preferring to mix a moderately dry concrete, others believing it better to have it very wet. Some consider that it should have about the consistency of freshly dug earth; others that it should flow more readily. There would appear to be a medium point, at which the best results are reached, the concrete being merely such that it can be consolidated readily, and well tamped against the casing, so that the mold will be entirely filled, and the surface of the work smooth, when the casing is taken away. With sufficient water, there is reason to believe that the hardening and crystallizing of the concrete is more perfect, and that a more compact



CONCRETE ARCH, NEAR ARTHUR—IN PROCESS OF CONSTRUCTION.

stone is produced. Concrete that is too dry cannot be fully consolidated, with the result that the surface is likely to be very rough, with deep holes in it, when the molds are removed.

### Clean Material.

It is very necessary to see that the sand and stone used in making the concrete do not contain an undesirable amount of clay, loam, vegetable or other matter which will act as an adulterant, and result in a weak and friable concrete. If such matter is intermixed with the stone it is well to flush it away with a stream of water. Large stone used in rubble cement should also be cleaned in this way. It is well, particularly in hot weather, to dampen broken stone before mixing it with the mortar. The heat of the stone in hot weather causes the moisture of the mortar to evaporate, causes it to set too quickly, and at all times there is more or less absorption from the mortar in immediate contact with the stone, unless the stone has been dampened.

### Mixing.

The concrete should be mixed at a point convenient to the work, on a platform which is sometimes specified as water-tight, but the concrete will quickly make it so. It should be mixed in just such quantity as is required, and a constant stream kept passing to the work. It should be placed in layers, and each layer thoroughly rammed until moisture appears on the surface. Concrete which has commenced to harden before being used, should be thrown away, as it will not set a second time.

In hand mixing, the sand and cement should first be mixed dry. About half the quantity of sand required in a batch is first spread evenly over the mixing board. On this is spread the dry cement, and then the remainder of the sand on top of the cement. When the sand and cement have been thoroughly mixed, by turning and re-turning with a shovel, a basin is formed by drawing the mixture to the outer edges of the board. The water required is then poured into the basin and the sand and cement thrown back, until uniformly wet. This mortar is then levelled, and the broken stone spread over it. The whole mass is then thoroughly intermixed until every stone is coated with mortar, and the mixture is of uniform color and consistency. Three or more turnings may be necessary.

The platform should be about 14 by 16 feet, a size on which four men can conveniently work, mixing one cubic yard at a time. The mixing should be done with short handled, square cornered shovels, the concrete being not merely turned over, but scattered by a twirling motion of the shovel. This twirling motion cannot be given with long-handled shovels. Energetic workmen who scatter the concrete in this way, can mix the material more perfectly in three handlings than indifferent men can do in half a dozen handlings by lazily turning the concrete over. The more thorough mixing can be aided by a man or boy raking the pile over, as it is shovelled together by the mixers. Some contractors prefer to use hoes in place of shovels, especially if workmen cannot be obtained who will handle the shovels properly. Good workmen can mix a batch of concrete, one cubic yard, in about fifteen minutes, the difference in time depending on the materials used, and the amount of mixing required. Mixing machines of varying merit are on the market, and as a rule do the work more thoroughly than by hand. The strength and durability of concrete depends on the thoroughness with which it is mixed, but the work must be done quickly, before the concrete begins to set.

### Depositing Concrete.

Concrete is usually deposited in layers of from 6 to 10 inches. It should be carefully put in place and consolidated with rammers weighing 10 or 15 pounds. It is not conducive to good results to tip the concrete from a height of several feet, as the light and heavy portions separate in falling, and the concrete is not uniform. It should be put in place by being wheeled in barrows and tipped into position, then at once rammed, the ramming to be fully completed before the concrete has commenced to set. The ramming should not occupy more than five minutes nor less than three.

When the work of one day has to be joined to that of the next, the last layer should be well compacted and finished with an excess of mortar. When partially set it should be scratched with a pointed stick to roughen it, then covered with straw, planks or canvas. Before putting on the next layer, the surface should be swept clean, moistened with water, and a wash of neat cement grout of the consistency of cream, thoroughly brushed into it. The next layer of concrete should then be at once spread and consolidated.

To secure a smooth, even surface, dependence should not be placed on a coating of mortar, as this is likely to scale off. It is much better to have a well constructed mold of dressed lumber, ramming the concrete close to it. By forcing a flat spade along the wet concrete next the timber, the coarse stuff is pressed in, and a space made into which the mortar will run. To oil the plank, is also conducive to a good surface finish.

When the work ceases for the day, or is for other reasons interrupted, the surface of concrete should be kept damp until work is resumed. When work is in progress in hot weather, any exposed surfaces should be kept damp and protected from the rays of the sun; otherwise the surface will, in setting too rapidly, be interlaced with hair-like cracks which, filling with water in winter, and freezing, will cause the surface to scale off. The same scaling sometimes results from laying concrete in frosty weather.

### PORTLAND CEMENT.

Portland cement is an artificial mixture of lime and clay in proper proportions, burned to a clinker and finely ground. It was first invented and



CONCRETE CULVERT IN TECUMSETH TOWNSHIP.

manufactured in 1824, by an English brickmaker, Joseph Aspdin, and derives its name from the resemblance which hardened mortar, made of it, bears to limestone quarried on the island of Portland, off the south coast of England, and which for centuries has been used as a building material. The lime used in its manufacture may be in the form of limestone or marl, the latter ordinarily occurring as a deposit in the bottom of small lakes. In Ontario, out of fourteen companies engaged in the manufacture of Portland cement, only one is using limestone, the remainder employing marl.

The quality of Portland cement depends upon the quality of the raw materials from which it is manufactured, the proportions in which they are

mixed, the degree to which they are burnt, the fineness of grinding, and the skill with which all details of manufacture are directed and carried out. The complete testing of cement is a process requiring somewhat expensive appliances, much experience, skilful manipulation and careful observation to secure accurate results. For this reason, in small works, reliance is ordinarily placed upon the use of a brand of known reputation. Even this may be at fault, as occasional batches of cement of a reliable brand, through carelessness in manufacture, may be bad. The following specification covers the principal qualities necessary to a safe cement, and is capable of ordinary municipal use.

### Specification for Portland Cement.

(1) All cement must be of a well and favorably known brand <sup>Brand and packages.</sup> of Canadian Portland cement, shall be free from lumps, and shall be delivered in barrels or equally weatherproof packages, each labelled with the name of the brand and the manufacturer. Any barrels or packages broken or torn at the time of delivery will be rejected.

(2) Immediately upon delivery, it is to be stored in a dry, <sup>Storage.</sup> well-covered, and well-ventilated building, or to be otherwise protected from rain and dampness by a suitable covering. Any cement affected by moisture before or after delivery shall be rejected from the work.

(3) At least 92 per cent. by weight shall pass through a No. <sup>Fineness.</sup> 100 sieve, having 10,000 meshes per square inch, and the whole shall pass a seive of 2,500 meshes to the square inch.

(4) A pat of pure cement, made as in Section 5 following, <sup>Rate of setting.</sup> must not have its initial set within thirty minutes, and its final set in not less than one hour nor more than ten hours after water is first added, the pat being kept in a moist air at a temperature between 65 and 70 degrees Fahr. The "initial set" and "final set" shall mean the time when the pat of cement will sustain a wire one-twelfth of an inch in diameter weighted to one-fourth of a pound, and a wire one-twenty-fourth of an inch in diameter, weighted to one pound, respectively, these to rest upon it without penetration.

(5) (a) Pats of pure cement with thin edges, half an inch thick <sup>Soundness.</sup> in the centre, and from two to three inches in diameter, moulded on pieces of glass, and immersed in water after "final set," shall not at any time thereafter show expansion cracks, distortion, curling of the thin edges, nor disintegration.

(b) Similar pats allowed to set in air, then placed in boiling water 48 hours shall not show any of the foregoing defects.

(6) A quantity of the cement is to be mixed with a sufficient <sup>Change of volume.</sup> quantity of water to enable it to be pressed into a glass tube of about one-half inch diameter. Should the cement swell so as to burst the glass, or shrink so as to become loose, either defect will be cause for the rejection of the cement.

(7) Pats moulded in the manner described in Section 5 of this <sup>Color.</sup> specification and kept in air must remain of a uniform bluish or greenish-grey color, exhibiting no yellow blotches nor discoloration.

(8) Samples of cement shall be made into the consistency of <sup>Tensile strength.</sup> a stiff mortar, and firmly pressed into moulds to form briquettes

one square inch in cross section. These, covered with a damp cloth, and allowed to develop "final set" in air, then immersed in water, shall show the following tensile strengths per square inch :—

Age.	Strength, lbs.
24 hours (in water after "final set") .....	175
7 days (1 day in air, 6 days in water).....	400
28 days (1 day in air, 27 days in water).....	500
7 days 1 day in air, 6 days in water), one part of cement to three parts of sand.....	125
28 days (1 day in air, 27 days in water), one of cement to three of sand .....	200

The sand used in the above mortar tests shall be clean and sharp, of the standard size, that passing a No. 20 sieve, but refused by a No. 30 sieve.

Specific  
gravity.

(9) The specific gravity of the cement determined from a carefully dried sample, shall be between 3.10 and 3.25.

Impurities.

(10) The cement shall not contain more than  $3\frac{1}{2}$  per cent. of magnesia, nor more than  $1\frac{3}{4}$  per cent. of sulphuric anhydride.

### Testing Portland Cement.

Test No. 3 indicates the degree of fineness to which the cement is ground, upon which its strength greatly depends. While fineness is not certain proof of the value of the cement, yet all cements are improved by fine grinding. If otherwise good, the finer the cement, the greater amount of sand it will take in making a good mortar. A fine cement will feel floury in the hand; a gritty feeling denotes coarse grinding.

Test No. 4 shows the time a cement will take to set, and while not an indication of the strength of the cement, it is a guide as to the work to which the cement is adapted. For submarine work, a quick-setting cement is often a necessity, but for work in the open air, a cement should not require too rapid manipulation in mixing and putting in place before it begins to set, especially for sidewalk, curb, bridge and similar construction. Where laboratory appliances are not available, a mortar or concrete may be regarded as having reached its final set when it will support a pressure of the thumb without indenting.

Test No. 5 (a) is most valuable and necessary, as it serves to detect one of the more dangerous defects, an excess of free lime. It is frequently the only test that need be applied. Some cements stand well for short periods but owing to the presence of free lime disintegrate after a few months. If, at the end of three days in water, the thin edges of the pats show no signs of cracking, curling, and disintegrating, technically known as "blowing," the cement may be considered safe in this regard. Fine air cracks on the upper surface of the pats, which cross and re-cross one another, are not due to blowing, but are caused by changes in temperature.

The cracks caused by blowing are usually accompanied by a certain amount of disintegration, are wedge-shaped, running from the centre of the pat. The boiling test, No. 5, (b) is an accelerated condition to show

in a few hours what would otherwise take a much longer period. It is frequently regarded as too severe for all cases, but most sound cements can pass it. Where blowing is developed, it should call for careful consideration rather than the rejection of the cement.

Test No. 6 is also indicative of the soundness of the cement, and any change in either expansion or contraction should cause the rejection of the cement. The cement may be watched for signs of blowing, as in No. 5.

In Test No. 7, in which pats of neat cement are allowed to set and remain in air, the color should continue uniform throughout, yellow blotches indicating an excess of clay, or that the cement is not sufficiently burned. Under the latter condition it is probably quick setting and deficient in strength. Blue indicates an excess of lime; dark green, a large percentage of iron. Variation of color, while indicating impurity, unless very marked or confirmed by other tests, should not be cause for rejection.

A deficiency in tensile strength, shown by Test No. 9, indicates the presence of too much magnesia, over 3 per cent, making a cement unreliable. This test is important, and is the only one demanding an instrument involving any special expense. Moulds are required in which to form the briquettes with exactness, and a means of applying and indicating a tensile stress is required, various instruments being in use for this purpose. This test requires considerable time to perform it perfectly, more than can be ordinarily taken.

Some cements develop considerable strength during a short interval, but fail to maintain it for a longer period. It is generally conceded, however, that for a brand of good reputation, the one-day test will show whether or not the sample is of its average quality, the seven-day test being, of course, preferable. It is sometimes required that manufacturers shall furnish a sworn statement as to the results of this test with each lot of cement delivered.

Tests for specific gravity, magnesia ( $MgO$ ), and anhydrous sulphuric acid ( $SO_3$ ) require delicate treatment and are seldom necessary. Weight is not a definite indication of quality, as much depends on the fineness of the cement, but ordinarily it should weigh from 84 to 88 pounds per cubic foot. A heavy cement, if coarsely ground, will be weak and will have no carrying capacity for sand. Light weight may be caused by fine grinding, yet it may also be caused by underburning. A cement weighing from 70 to 80 pounds per cubic foot is generally weak.

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## SPECIFICATIONS FOR CONCRETE BRIDGES, ABUTMENTS AND PIERS.

(1) All work performed under these specifications shall be in accordance with the plans and drawings hereto attached, forming part of these specifications, and shall be completed to the lines and levels given by the engineer. No stakes or benchmarks placed for this purpose by the engineer shall be moved or effaced by the contractor without the permission of the engineer. Levels, plans  
and location.

### Materials.

Portland  
cement.

(2) All cement employed in the work must be of a favorably known brand of Portland cement, and approved by the engineer or inspector in charge of the work. It shall be delivered in barrels or equally tight receptacles, and after delivery must be protected from the weather by storing in a tight building or by suitable covering. The packages shall not be laid directly on the ground, but shall be placed on boards raised a few inches from it.

Fine and  
rubble con-  
crete.

(3) Concrete referred to in this specification shall be known as "fine concrete" and "rubble concrete," the former to consist of a mixture of gravel and cement, or of broken stone, sand and cement; the latter to consist of fine concrete with large stones imbedded therein. Unless rubble concrete is definitely specified fine concrete shall be used.

Stone, sand  
and water.

(4) Broken stone used shall be granite, quartzite, fine-grained limestone, or other equally strong and durable stone, care being taken to exclude soft limestone, friable sandstone, and stone affected by the atmosphere. It shall be broken into varying sizes, the largest, unless elsewhere defined, to pass any way through a two and one-half inch ring. Sand used shall be clean, sharp, silicious, and of varying sized grain. The water used shall be clean, and the amount to be used and the consistency of the mortar and concrete shall be subject to the approval of the engineer or inspector, but may vary in different portions of the work.

Gravel.

(5) Gravel, if used in its natural state in making "fine" concrete, shall be of uniform character and of varying sized grain, making a dense and compact mass, such that the smaller particles will fill the voids between the larger, the largest stones therein to pass any way through a two and one-half inch ring; it shall be clean and free from earthy mould or organic matter. Should there be insufficient fine material to properly fill the voids and make a compact mass, the deficiency shall be corrected by the addition and mixing of such quantity of sand, and in such manner as may be required by the engineer or inspector in charge of the work. Should the gravel to be used contain an excessive amount of sand, loam, large stones, or other objectionable material, it shall be screened through a mesh of proper size. Where the sand and fine stuff is thus removed the resulting mass of pebbles shall be treated as broken stone, and sand shall be mixed therewith in the manner herein described for broken stone concrete. Where large stones only are removed the material shall be treated in the ordinary manner for gravel concrete.

### Proportioning the Materials.

Proportions of  
gravel, sand  
and cement.

(6) The proportions of materials to be used in the mixing of fine concrete shall be by weight, and unless elsewhere more definitely specified, shall be as follows:—

#### GRAVEL CONCRETE.

(a) Abutments, piers and wing walls: one part of Portland cement to seven parts of gravel.

(b) Arches from springing line; one part of Portland cement to five parts of gravel.

(c) Flat tops of bridges or culverts; same as for arches (b).

(d) Parapet or sidewalls; same as for arches (b).

#### BROKEN STONE CONCRETE.

(e) Abutments, piers and wing walls; one part of Portland cement, three parts of sand and six parts of broken stone.

(f) Arches from springing line; one part of Portland cement, two parts of sand and four parts of broken stone.

(g) Flat tops of bridges or culverts; same as for arches (f).

(h) Parapet or side walls; same as for arches (f).

Should any variation be required from the proportions as here or elsewhere defined, the amount to be added to or deducted from the contract price shall be determined by the engineer in charge. The ingredients for all concrete shall be carefully measured to insure correct proportions.

#### Mixing Concrete.

(7a) Where gravel is used for fine concrete the concrete shall Fine concrete. be mixed on a water-tight box or platform placed close to the work, by first spreading evenly a layer of gravel, upon this shall be spread a proportionate quantity of cement, and the two thoroughly intermixed in a dry state. To this sufficient clean water shall be slowly added; and the whole again thoroughly mixed and brought to a proper consistency. Gravel.

(b) Where broken stone is used for fine concrete the concrete shall Broken stone. be mixed on a water-tight box or platform placed close to the work, by first spreading evenly a layer of sand, upon this shall be evenly spread the proportionate quantity of cement, and the two thoroughly mixed in a dry state. To this water shall be added, and the whole thoroughly mixed until a good mortar is formed. The proportionate amount of stone after being dampened, shall then be spread evenly over the mortar and thoroughly intermixed therewith.

(8) Cement mortar shall be a mixture of sand and cement in Cement mortar. the required proportions; the sand and cement to be first mixed in a dry state, then sufficient water added to properly moisten, and the whole again thoroughly intermixed. Where cement mortar is applied to a concrete base it shall be put in place before the latter has set, so that a perfect bond between the two shall be secured, the surface to be floated and trowelled until smooth and even, and otherwise marked as required for the work in which it is used.

(9) Within the body of the abutments, piers and wing walls Rubble concrete. of not less than four feet span, but not nearer than six inches to the surface in any direction, stones not larger than one man can readily lift, may be placed by hand in layers. These stones shall be in "rack and pinion" order, and not less than two inches apart. In hot weather the stones shall be dampened before placing in the concrete; or, if dirty, the stones shall be well flushed to remove the earth, loam or objectionable material. Concrete shall be carefully inserted between the stones thus placed and thoroughly packed and rammed so as to fill all voids. Concrete shall cover

each layer of stones to a thickness of half the depth of the stones, when another layer of stones may be placed. A facing of fine concrete is at all times to be kept at least six inches higher than the rubble concrete, and shall be united with the rubble concrete so as to form a continuous and solid mass. This outer rim of concrete shall precede the placing of the rubble work within, and shall be placed around the interior of the casing to a thickness of six inches. It is to be thoroughly pounded so that no cavities shall remain when the outside casing is removed. In no instance is the rubble concrete to extend higher than one foot below the top of the pier, wing wall or abutment, which top of pier, wing wall or abutment shall be finished with fine concrete rich in cement. The rubble stone is not under any circumstances to extend into a coping, arch or floor.

### Putting Concrete in Place.

Laying the  
concrete.

(10) While the work is in progress it shall be so arranged that a steady supply of mixed concrete shall pass from the mixing box to the point where it is to be placed. At any time when the work is interrupted before its completion, or at the end of the day, a wet covering shall be placed over the last layer of concrete; before the work of depositing the concrete is resumed this surface shall be thoroughly flushed with water to remove any foreign material which may have gathered thereon, and coated with neat cement mortar. No concrete shall be laid in wet or freezing weather. When laid in hot weather the concrete shall, by means of dampened canvas, wet sand, sawdust, or other approved means, be protected from the direct rays of the sun for at least five days. Any concrete left over at noon or any time until it begins to set, is not to be remixed or used in the work. When moulds are removed, if the external surfaces are not perfectly full and smooth, they shall be made so by trowelling with mortar composed of equal parts of sand and cement, the coating of mortar to be no thicker than is absolutely required to obtain a straight and even surface.

Concrete  
under water.

(11) Concrete shall preferably be laid under water by means of a coffer-dam, from which the water is wholly removed, and any other method adopted must be approved by the engineer. Dumping into the water from a wheel-barrow or other appliance, or shovelling in, will not be allowed. Special care must be taken in laying the base of a pier or abutment around the head of piles, to provide that the concrete shall be of sufficient strength and durability, by increasing the proportion of cement or otherwise as directed by the engineer or inspector in charge.

Molds, coffer-  
dams, etc.

(12) The contractor is to make all necessary provision, at his own expense, for constructing moulds or false-work for the abutments, piers, wing walls, arch, flooring or other work included in this contract; also for the construction and maintenance of coffer-dams and platforms, and for pumping and unwatering, as may be necessary, to enable the work to be properly carried out. The abutments and wing walls are to be erected within a substantial and well-constructed framework of dressed and well fitted lumber, with vertical posts and braces, the planking to be not less than  $1\frac{1}{2}$  inches in thickness, closely boarded up against the

work. The centring for an arch must be well formed, curved with the exact radius as shown upon the plans. The ribs must not be farther apart than  $2\frac{1}{2}$  feet, and the lagging will be two inches thick, dressed to the inside surface of the arch. Care shall be taken to make a smooth, regular surface, with perfectly fitted joints. Proper moulds of dressed lumber at least  $1\frac{1}{2}$  inches in thickness must be provided for exposed surfaces. The concrete shall be perfectly rammed into place so that all surfaces shall be smooth, without cavities, when the casing is removed. The posts, shoring and ribs are to be sufficiently close together to render the mould practically unyielding when the concrete is being tamped or rammed. No mould is to be removed without the permission of the engineer or commissioner in charge of the work.

### Abutments and Wing Walls.

(13) Should it be necessary to extend the piers, abutments and wing walls to a greater depth than is provided by the plans, the bottom widths shall be continued with a minimum batter as indicated upon the said plan. The base or footings shall extend to the required widths around the bottom of the wall. Wing walls shall be constructed at such angle with the abutments and with such dimensions as shall be given by the engineer or commissioner in charge of the work. Dimensions.

(14) An excavation of the depth indicated upon the plans shall be made below the present bed of the stream and to the full width of the footings, the bottom to be made perfectly level before beginning to lay the concrete. Should a greater depth be necessary to provide a firm foundation, it shall be made as directed by the engineer or commissioner in charge of the work; all excavated earth to be disposed of as directed by the said engineer or commissioner. Excavation and footings.

(15) The abutments and wing walls shall be constructed of fine and rubble concrete. Large stones for rubble concrete shall be approved by the engineer or commissioner in charge of the work, otherwise fine concrete only shall be used. Concrete.

(16) The abutments, piers and wing walls herein referred to shall include those erected for steel or other superstructure, also for concrete arches and square-top structures. Abutments defined.

### Arches and Square Tops.

(17) Concrete for arches and for the square tops of bridges and culverts, whether used with or without metal reinforcement shall be in all respects in accordance with the requirements for fine concrete. Gravel or broken stone used, shall be such as will pass through a  $1\frac{1}{2}$  inch mesh. Arch concrete.

(18) The metal reinforcement may be wire netting, expanded metal, steel bars, steel beams, or other approved material as indicated upon the plans hereto attached. Care must be taken to fully imbed the metal within the concrete at the points shown on the said plans, and where required to provide sufficient tensile strength. Wire or other light metal reinforcement may be first laid over the framework in the desired position, a layer of fine concrete to Metal reinforcement.

be then spread over the metal. By means of a suitable hook, and while the concrete is plastic, the metal shall be lifted above the concrete, permitting the concrete to drop under and fully surround the wire. More concrete shall then be added and the whole firmly tamped and rammed so as to thoroughly compact the bed of concrete, to the depths shown upon the plans.

Steel beams.

(19) Where steel I-beams are used they shall be of medium wrought steel made by the open hearth process, and shall be of the number, form, weight, and spacing indicated upon the said plans, and of a quality approved by the engineer. They must be free from all injurious flaws, cracks caused either in rolling or binding, and shall otherwise conform to the standard for medium steel as required by the Ontario Steel Bridge Specifications.

(20) Steel I-beams used in the reinforcement of an arch shall be bent in the plane of the web to the exact radius shown upon the plans hereto attached, and shall be placed at a distance of ..... feet centre to centre as shown on the said plans. A channel beam placed transversely shall be bolted by means of knee clamps to the ends of the I-beams. The arch or top shall be further reinforced by steel rods  $\frac{3}{8}$ -inch in diameter, laid transversely on the upper side of the I-beams, at a distance of ..... inches centre to centre, with ends bent over the outside flange of the I-beams.

Depositing  
concrete  
around  
steel beams.

(21) Where concrete is being deposited around steel I-beams, either in an arch or square top bridge, the false work may be supported to the beams by suitable wires placed sufficiently close together to ensure perfect rigidity. Care must be taken to fill the space between the lower side of the I-beams and the lagging and have it properly rammed into place, the I-beams to be perfectly imbedded in the concrete.

Reinforcement  
of parapet  
wall.

(22) Concrete retaining or parapet walls along the side of an arch or bridge shall be reinforced with steel bars of  $\frac{3}{8}$ -inch diameter; there to be not less than two lines of such bars placed three inches from the top of the walls and close to each side of the guard rail posts, and one line near the bottom of the posts close to the inner side.

### Railings and Approaches.

Guard railings.

(23) Guard-railings shall be placed on each side of the bridge. They shall be strong and durable, rigidly braced, and shall extend over piers and abutments. The posts shall be securely imbedded in the concrete retaining wall.

Steel lattice.

(24) In steel lattice railings, the openings in the lower half of the fence shall not exceed nine inches square, and the bottom rail shall not be more than six inches from the top of the parapet wall.

Gas pipe.

(25) In railings made of gas pipe, the posts shall be of larger diameter than the railing, and the piping for the top railing shall be not less than  $1\frac{1}{2}$  inches diameter. Railings shall be strongly coupled and attached to the posts by means of a loop or ball of iron.

Steel angle  
posts.

(26) Posts made of steel angles shall be not less than 4 by 3 by  $\frac{7}{16}$  inches. Holes shall be drilled at proper distances to receive the rail attachment which shall be riveted hot.

(27) The railing shall be given two coats of red lead paint, Painting. one before erection and the other immediately after the work is completed.

(28) The roadway of the bridge shall be surfaced with a coat- Gravel surface of roadway. ing of gravel at least ..... inches in thickness over the centre of the arch and properly crowned, with a grade of two inches in ten feet from the centre to either end of the bridge. The approaches to the bridge shall be uniformly and evenly graded with a width of at least 18 feet at the top of the grade, and shall be crowned transversely. In filling behind the abutments and wing walls the earth must be properly packed and rammed, and this must be done before the concrete is placed in the arch.

## SPECIFICATIONS FOR STEEL HIGHWAY BRIDGES.

### Material.

1. The structure shall, except the flooring, hand-rails, and wheel guards, be of medium wrought steel. Rivets and bolts are Material in bridge. to be of soft steel. Cast iron will not be used in any part of the work, unless provided for by supplementary clause. If important castings are necessary they shall be of cast steel.

### Girders and Trusses.

2. The general type of girders and trusses may be determined Design of bridge. by the bidder, but shall preferably be:—

- (1) Rolled beams for spans up to 30 feet.
- (2) Riveted low truss for spans of 30 feet to 90 feet.
- (3) Riveted through truss for spans of 90 feet to 250 feet.
- (4) Pin-connected or riveted truss for spans of 200 feet to 300 feet.
- (5) A deck bridge will be preferred wherever suitable.
- (6) Warren and Pratt trusses will be favorably considered up to spans of 250 feet; over 250 feet the Petit truss.

It is understood that the foregoing limiting lengths are not absolute, but may be varied.

### Loads.

3. Each structure shall be designed to carry:—

Dead loads.

(1) A fixed or dead load, consisting of the weight of metal or other material in the span, floor and guards; the weight of oak or other hardwood to be assumed at  $4\frac{1}{2}$  lbs. per foot board measure; white pine and soft woods,  $3\frac{1}{2}$  lbs.; concrete, per cubic foot, 150 lbs. Unless otherwise directed, the dead load shall provide for the use of steel stringers and concrete floor.

(2) A live or moving load in accordance with one of the following classes "A" or "B" or as may be elsewhere herein specified. Live loads.

Class "A"—Bridges suitable for towns and main country roads.

4. The truss load for spans 100 feet and under shall be 100 Truss load. pounds a square foot; for spans 200 feet and over, 60 pounds a

square foot; for spans of intermediate length, the weight to be reduced uniformly from 100 pounds to 60 pounds a square foot.

Floor load. 5. The floor and its supports or any part of the roadway shall be proportioned to a concentrated load of 15 tons on two axles at 10 feet centres, and the remaining portion of the floor, including sidewalks, to a uniform load of 100 pounds for each square foot of floor.

Class "B"—Bridges suitable for the lighter and less constant country travel and traffic.—

Truss load. 6. The truss load for spans 100 feet and under shall be 80 pounds a square foot; for spans 200 feet and over, 50 pounds a square foot; for spans of intermediate length, the weight to be reduced uniformly from 80 pounds to 50 pounds a square foot.

Floor load. 7. The floor and its supports or any part of the roadway shall be proportioned to a concentrated load of ten tons on two axles at ten feet centres and the remaining portion of the floor, including sidewalks, to a uniform load of 80 pounds for each square foot of floor.

Calculations and Unit Stresses.

Proportioning members. 8. All parts of the structure shall be proportioned to sustain the maximum stresses produced by the live and dead loads and wind forces.

Length of spans. 9. The length of spans shall be the distance between centres of end-pins of trusses, and between centres of bearing plates of beams and girders.

Length of stringers. 10. The length of stringers shall be the distance between centres of floor-beams, and the length of floor-beams the distance between centres of trusses.

Length of posts. 11. The length of posts shall be the centre to centre distance between pins.

Proportioning Material in Tension.

Material in tension. 12. All parts in tension shall be proportioned in accordance with the following unit strains per square inch of cross-section, in pounds, for medium steel:—

On longitudinal, lateral and sway bracing, for wind and live load strains, 18,000 pounds per square inch.

On solid rolled beams, used as floorbeams and stringers, 13,000 pounds per square inch.

On floorbeam hangers and other similar members liable to sudden loading (bars with forged ends), 9,000 pounds per square inch.

On floorbeam hangers and other similar members liable to sudden loading (plates or shapes) net section, 8,000 pounds per square inch.

Live loads. Dead loads.

Bottom chords, main diagonals, counters and long verticals (forged eye bars) .....	15,000	25,000
Bottom chords and flanges. main diagonals, counters and long verticals (plates or shapes) net section .....	12,500	22,000

Soft steel in tension. 13. Soft steel may be used in tension, with strains 10 per cent. less than those allowed for medium steel.

Proportioning Material in Compression.

14. All parts in compression shall be proportioned by the following unit strains per square inch of cross-section in pounds, for medium steel; "l" representing the length of the member in inches centre to centre of end connections; and "r" the least radius of gyration in inches.

Chord segments and end posts, live load.....	12,000—	55—	$\frac{l}{r}$
dead load.....	24,000—	110—	$\frac{l}{r}$
Intermediate posts of through bridges, live load.....	10,000—	45—	$\frac{l}{r}$
dead load.....	20,000—	90—	$\frac{l}{r}$
Intermediate posts of deck bridges, live load.....	11,000—	50—	$\frac{l}{r}$
dead load.....	22,000—	100—	$\frac{l}{r}$
Lateral struts and rigid bracing, live-load and wind strains .....	13,000—	70—	$\frac{l}{r}$

15. Soft steel may be used in compression with strains 15 per cent. less than those allowed for medium steel.

16. To determine the sectional area of any member, the areas obtained by dividing the live load strains by the live load unit strains shall be added algebraically to the areas obtained by dividing the dead load strains by the dead load unit strains.

17. Members and their connections subject to alternate strains of tension and compression shall be proportioned to resist each kind of strain separately. Both of the strains shall be increased by an amount equal to  $\frac{1}{10}$  of the lesser of the two strains, for determining the sectional areas by the allowed unit strains.

18. A member subjected to both axial and bending strains shall be so proportioned that the greatest fibre strain shall not exceed the allowed unit strains for tension or compression.

19. In long span bridges, when the ratio of the length to the width of span is such that the top chords taken as a whole is a longer column than the segments of the chord, the chord should be proportioned to the greater length.

Length in  
compression.

20. The length of a compression member shall not exceed 100 times its least radius of gyration for main members; nor 120 times its least radius of gyration for laterals.

Flanges.

21. Compression flanges of beams shall be of the same gross section as the tension flanges.

Rolled beams.

22. Rolled beams shall be proportioned by their moments of inertia.

Counter  
braces.

23. The area of counter braces shall be determined by the difference in areas of live and dead loads taken separately, only 70 per cent. of the dead load stress to be applied toward counteracting the live load stress.

### Bearing, Shear and Bending.

Pins and  
rivets.

24. Except rivets of floor and lateral systems, and field rivets, maximum shear and bearing stresses in pounds per square inch shall not exceed the following:—

Shear on rivets and pins .....	10,000
Bearing on diameter of rivets and pins .....	18,000
Bending on pins, centre to centre of bearing .....	20,000

Floor systems.

25. Intensities for floor systems, including hanger connections, shall not exceed 80 per cent. of above limits, and for lateral and sway bracing may be 40 per cent. in excess. Intensities for field rivets and bolts shall not exceed 75 per cent. of the foregoing limits.

Direct tension.

26. Rivets and bolts shall not be used in direct tension.

### Wind Strains.

Lateral  
bracing.

27. In spans of 200 feet or less the top lateral bracing in deck bridges and the bottom lateral bracing in through bridges shall be proportioned to resist a lateral force of 300 pounds per foot of span, 150 pounds of which shall be treated as a moving load. The bottom lateral bracing in deck bridges and the top lateral bracing in through, shall be proportioned for a lateral force of 150 pounds for each foot of span. For spans exceeding 200 feet, add 10 pounds for each additional 30 feet, in each of the foregoing cases.

Truss members.

28. Strains in truss members from assumed wind forces need not be considered except to provide:—

(a) That the wind strains on any member shall not exceed by more than 25 per cent. the maximum fixed for dead and live loads.

(b) That the wind strain alone, or combined with a possible temperature stress, shall not neutralize or reverse the strains in any member.

### General Dimensions.

Widths and  
head-room.

29. The general dimensions shall be as elsewhere specified, but in all cases, from the top of the floor to the under side of the top lateral bracing of through bridges, there shall be a minimum head-room of 14 feet. Sidewalks shall not be less than 4 feet wide, nor the clear width of roadway less than 14 feet. The specified width of sidewalk shall be the distance from the centre of truss to the centre of railing on the outer edge of the walk. The clear width of roadway shall mean the clear distance between flange plates or cover plates of end posts.

**Co-Efficient for Friction.**

30. Wrought iron or steel on itself .....	15 per cent.	Friction.
Wrought iron or steel on cast iron .....	20 "	
Wrought iron or steel on masonry .....	25 "	
Masonry on itself .....	50 "	

**Bearing on Masonry.**

31. Bed-plates must be of such dimensions that the greatest pressures shall not exceed those given in the following table:—

	Pressure per square inch.
Natural cement concrete .....	150 pounds.
Portland cement concrete, sandstone or ordinary limestone .....	300 "
Extra good limestone .....	400 "
Granite .....	500 "

**Net Section.**

32. The effective diameter of driven rivets shall be assumed the same as before being driven. In estimating net sections of rivets and rivet holes. members, rivet holes shall be assumed to have a diameter of  $\frac{1}{8}$  inch longer than the undriven rivet.

33. The rupture of a riveted tension member is to be considered as equally probable, either through a transverse line of rivet-holes or through a diagonal line of rivet holes where the net section does not exceed, by 30 per cent., the net section of the transverse line. Rupture of tension members.

34. The number of rivet holes to be deducted for net section shall be determined by the foregoing condition.

**General Construction.**

35. Workmanship and construction throughout shall be first-class. Sharp or unfilleted angles shall not be permitted. Portions exposed to view must be neatly finished. Workmanship.

36. Construction, material and design throughout must be such that rupture will occur in the body of members rather than in any of their details or connections. Rupture.

37. Members, and the several pieces when formed into one member shall be free from twists and bends. Twists and bends.

38. Details must, as far as practicable, be accessible for cleaning, painting and inspection; closed sections shall not be allowed. Details.

39. The minimum thickness of material to be used in main members and their connections shall be  $\frac{5}{16}$  inch; and in laterals and their connections  $\frac{1}{4}$  inch. Minimum thickness.

40. The ends of all square ended members shall be planed smooth and exactly square to the centre line of strain. Square ends.

41. Where floor timbers are supported at their ends on the flange of an angle, the vertical leg of the angle must have rivets spaced not over 4 inches apart. Shelf angles shall not be less than 5 inches by  $3\frac{1}{2}$  inches by  $\frac{5}{8}$  inch with the  $3\frac{1}{2}$  inch leg turned up. Shelf angles.

- Camber. 42. All truss bridges shall be cambered by making each panel of the upper chord longer than the lower chord in the proportion of  $\frac{1}{8}$  inch in 10 feet.
- Screw ends. 43. Bars having screw-ends shall be upset so that the minimum diameter through the threaded portion shall be  $\frac{1}{16}$  inch greater than any part of the body of the bar. The smallest section of any bar shall have a net area not less than  $\frac{3}{4}$  inch.
- Rigid members. 44. In through bridges the end vertical suspenders and two panels of the lower chord shall be rigid members.
- Lattice trusses and girders. 45. The members of lattice trusses and girders must be double and connected symmetrically to the webs of chords. Where it can be avoided plates or flats alone must not be used for tension members. In lattice trusses the counters, suspenders and two panels of the lower chord at each end must be latticed; all other tension members may be connected by batten plates or latticed.
- Temperature. 46. Provision shall be made for variation from change of temperature to the amount of  $\frac{1}{8}$  inch in 10 feet. Slotted holes must be provided in sliding plates long enough to prevent any possible shearing of the anchor bolts; the slotted holes to be covered by plate washers and to be large enough to take a piece of pipe around the bolt to screw against so that the washer will not bind on the sliding plate.
- Waterproofing. 47. Spaces where water will have a tendency to collect must be filled with water-proof material. All stiffeners, fillers, splice plates and riveted members must fit sufficiently close to prevent, when painted, the admission of water.

### Rivets.

- Diameter. 48. For main members  $\frac{7}{8}$  inch rivets will preferably be used, with  $\frac{3}{4}$  inch rivets for lateral members.
- Pitch. 49. The pitch of rivets in any class of work is not to be less than three diameters of the rivet, nor shall it exceed 6 inches, or 16 times the thinnest outside plate.
- Grip. 50. Rivets shall be not less than  $1\frac{1}{4}$  inches from the edge of the metal through which it passes when the size of the piece will permit. No rivet shall have a longer grip than five times its diameter.
- Dies. 51. Dies shall not exceed the diameter of rivet by more than  $\frac{1}{16}$  inch and all holes must be clean cuts without torn or ragged edges.
- Rivet holes. 52. Rivet holes shall be accurately laid off and punched in such a manner that, when the several pieces forming a member are bolted up, the holes will match accurately throughout.
- Drifting. 53. Drifting shall not be allowed. Holes requiring it must be reamed. Hot rivets should enter the holes without the use of a hammer.
- Driving. 54. Rivets shall be power driven whenever practicable and field riveting must be reduced to a minimum. Hand driven rivets shall not be allowed in the case of rivets exceeding  $\frac{7}{8}$  inch diameter.
- Loose rivets. 55. Rivets must completely fill the holes, and no loose or badly formed rivets will be allowed nor any calking. They must have full round heads concentric over the shank of the rivet.

56. Holes for field rivets, except those for connections of the lateral and sway systems, shall be accurately drilled or reamed to an iron template, or be reamed true while the parts are temporarily fastened together. Field rivets.

57. Rivets must be heated uniformly throughout or with the heads hotter than the points. Under no circumstances shall rivets be driven with points hotter than the heads. Rivets must not be burned. Rivets that "spit" on being taken from the furnace shall be thrown away. Burned rivets.

### Rolled I-Beam Spans.

58. The system of rolled I-beams shall preferably be not less than  $\frac{1}{20}$  of the span. System.

59. I-beam spans shall have planed sole-plates riveted to the flanges, and bolted through bed-plates to the masonry at one end and free to slide longitudinally at the other. They shall have rigid cross-struts and transverse bracing riveted to the webs. There shall be stiffening angles at both ends with close fit to flanges; when in pairs they shall have wrought metal separators. Sole-plates and bracing.

60. Holes in flanges shall be drilled and holes in webs may be punched. Holes.

### Compression Members.

61. Compression members shall be of steel, and of approved forms. Material and form.

62. The material in compression chord sections and end posts must be concentrated principally at the sides in the angles and vertical webs. Not more than one plate shall be used, this preferably not to exceed  $\frac{3}{8}$  inch in thickness. Chord sections and end-posts.

63. Ends of compression members forked to connect to the pins must have a compressive strength equal to the body of the members. Forked ends.

64. At the ends of compression members, for a length equal to twice the width of the member, the pitch of rivets shall not exceed four diameters of the rivets. Pitch of rivets.

65. The distance between rivet lines in plates subject to compression shall not exceed 30 times their thickness; except cover plates of top chords and end posts, in which the unsupported width shall preferably not exceed 40 times their thickness; but where a greater width is used for chords and end posts, only 40 times the thickness shall be considered as effective section. Rivet lines.

66. Eccentricity shall be avoided in all parts of the structure. All parts working together as one member shall be uniformly stressed. Eccentricity

67. The open sides of compression members shall be stayed by batten plates at the ends, and diagonal lattice-work at intermediate points. Batten plates shall be placed as near the ends as practicable and shall have a length not less than the greatest width of the member or  $1\frac{1}{2}$  times its least width. Batten plates and lattice.

### Stringers and Floor Beams.

- Stringers. 68. Stringers shall be of steel, spaced not more than  $3\frac{1}{2}$  feet centre to centre.
- Rivets and hitch angles. 69. Stringers and floor beams shall preferably be carried by rivets at their ends, all such ends to be faced true and square, and to exact lengths. The thickness of hitch angles must provide for such facing without reducing the required effective strength of the end angles. Hitch angles shall have a full complement of rivets.
- Fastening. 70. If stringers rest on the floor beams, they shall be securely fastened to them.
- Floor beams. 71. Floor beams shall preferably be riveted to the posts above or below the pins. Floor beam hangers, if used, shall be made without adjustment, and shall be readily accessible for inspection.
- Movement. 72. Floor beams shall be effectually stayed against end motion or tendency to rotate from action of the lateral system.

### Lattice Bars.

- Width and thickness. 73. The minimum width of lattice bars shall be  $1\frac{1}{2}$  inches for members 6 inches wide;  $1\frac{3}{4}$  inches for members 9 inches wide; 2 inches for members 12 inches wide;  $2\frac{1}{4}$  inches for members 15 inches wide; and  $2\frac{1}{2}$  inches for members 18 inches or more in width. The thickness of single lattice bars shall be not less than  $\frac{1}{6}$  of the distance between the rivets connecting them to the members.
- Angle. 74. Single lattice bars shall make an angle of not less than 60 degrees with the axis of the members, and double lattice bars with riveted connections, an angle of not less than 45 degrees.
- Double lattice. 75. Double lattice shall be used on all members having a clear width between members of 20 inches or more, the bars to be connected by a rivet at the intersection.

### Bed Plates, Shoes, Etc.

- Pedestals. 76. Pedestals must be of approved design and must properly distribute the loads over the bearings or rollers. Bearing surfaces of base plates and vertical webs must be planed.
- Bed-plates. 77. Under pedestals at both ends there must be bed plates or bearings of an approved form, of sufficient thickness to distribute the weight properly on the masonry; the minimum thickness for trusses to be  $\frac{7}{8}$  inch.
- Fox-bolting. 78. Bed plates and bearings must be fox-bolted to the masonry, fox-bolts for trusses to be not less than  $1\frac{1}{4}$  inches diameter, and for girders or beams not less than  $\frac{7}{8}$  inch diameter. The contractor must drill all holes, furnish bolts, and set to place with Portland cement. *Vide Sec. 46.*
- Sliding plates. 79. Bridges of 85 feet span or less shall be secured at one end to the masonry, and the other shall be free to move longitudinally on smooth surfaces.
- Friction rollers. 80. Bridges exceeding 85 feet span shall have at one end a nest of friction rollers bearing on planed surfaces.

81. The motion of the rollers shall be efficiently guided, and construction shall, as far as possible, be such that the entrance of dirt will be prevented, that rollers and bearings will not retain water, and that they may be readily cleaned. Design of rollers and bearings.

82. Rollers must be not less than 3 inches in diameter for spans, up to 100 feet, this diameter to be increased in the proportion of one inch for 100 feet additional span. The length shall be such that the pressure in pounds per lineal inch of roller will not exceed the product of the diameter in inches by 300. Size of rollers.

83. Rollers must be turned, of machinery steel; and bearing plates must be of medium steel, with planed surface. Material.

84. Where ends of two spans rest on the one pier or abutment a continuous bed plate, not less than  $\frac{1}{2}$  inch thick shall extend under the two adjacent bearings; otherwise the two bearings must be rigidly fastened together. Bearings for two spans.

85. Expansion ends must be free to move longitudinally under any possible changes of temperature, but shall be firmly fixed against lifting or side motion. End motion.

### Eye Bars.

86. All eye bars must be of medium steel. Material.

87. The heads and necks of eye-bars shall be of such dimensions as will develop the full strength of the bar. They shall be formed by up-setting and forging. Welding shall not be allowed. Bars must be annealed after forging. Up-setting and forging.

88. The bars must be straight before boring, the pin holes to be in the centre of the head and on the centre line of the bar. An error in diameter of pin hole or calculated length of bar exceeding  $\frac{1}{64}$  inch shall not be allowed. Boring pin holes.

89. Bars to be placed side by side in the same panel are to be bored in such manner that, when laid on top of one another, the pins will pass through the holes at both ends without driving. The bars of a set shall be laid symmetrically around the centre of pin and shall be as nearly parallel as possible. Bars in same panel.

### Pins.

90. Pins over 7 inches in diameter must be forged. Blooms for pins shall have at least three times the area of the finished pins. Blooms.

91. Lateral pins, and pins of  $4\frac{1}{2}$  inches diameter and upwards, shall fit the pin holes within  $\frac{1}{32}$  inch, and pins of less diameter within  $\frac{1}{50}$  inch. Fitting pin holes.

92. Pins shall be turned straight and smooth, of a smaller diameter at the ends, and driven to place with a pilot nut. Turning and driving.

93. The several members attached to the pin shall be so packed as to permit the least bending moment upon the pin, all vacant spaces to be filled with wrought iron filling rings. Vacant spaces.

94. Standard hexagonal nuts shall be used, and if not recessed, a washer for adjustment shall be used under at least one nut. Nuts.

**Pin Holes.**

Pin holes.

95. Pin-holes must be exactly perpendicular to a vertical plane passing through the centre line of the member when in the position it is to occupy in the structure. When necessary they shall be so reinforced by plates that the allowed pressure on the pins will not be exceeded, the plates to contain enough rivets to transfer their portion of the bearing pressure. At least one plate on each side shall extend six inches beyond the edge of the batten plates.

**Bolts.**

Bolts.

96. Bolts must be of neat lengths, must have hexagonal heads and nuts, and when in contact with wood shall have a washer under the heads and nuts. Holes in members to be connected by bolts must be reamed parallel and the bolts turned to a driving fit.

**Splices and Connections.**

Splicing riveted members.

97. Joints of riveted members, whether in tension or compression shall be fully and symmetrically spliced, abutting ends in compression to be connected by splices sufficiently strong to hold them in true position.

Abutting ends.

98. Abutting ends must be dressed straight and true, and brought into close contact when fitted with splice plates, rivet holes to be reamed in position before leaving the works.

Effective section.

99. Riveted tension members, with pin hole connections, must have, through the pin-holes, an effective section 50 per cent. greater than the net section area of the member, and the net section area back of the pin hole must be equal to the net area of the member.

Material.

100. Splices must be of the same kind of steel as the parts joined.

**Portals and Bracing.**

Latticed portals.

101. High truss bridges shall have latticed portals rigidly connected to the end posts and top chords, and as deep as the head-room will permit. Provision shall be made in the end posts for bending strains from wind pressure.

Diagonal bracing.

102. Trusses exceeding 20 feet in height shall have an overhead system of diagonal bracing attached to each post and to the top lateral struts.

Knee braces.

103. Trusses 20 feet or less in depth shall have knee braces at each intermediate panel point, and connected to the vertical posts and top lateral struts.

Pony trusses.

104. Pony trusses and lattice girders shall be firmly stayed by knee braces or gusset plates extending from the top chords to the cross beams or the transverse struts.

Portal bracing shapes.

105. Portal bracing must be made of shapes capable of resisting compression as well as tension, and must have riveted connections, laterals to be of shapes with riveted connections, but to carry tension only.

End laterals.

106. All bridges must have lateral struts at the ends unless the end floor beams act as such.

107. Members of the web, lateral, longitudinal or sway systems shall be securely fastened together at their intersections to prevent sagging and rattling. Sagging and rattling.

### Steel.

108. All steel must be manufactured by the open hearth process, and must be uniform in character for each specified kind. Manufacture.

109. The maximum limits of phosphorous shall be as follows: Phosphorous.  
Acid open hearth steel, 0.06 of one per cent.; basic open hearth steel 0.04 of one per cent.

110. Finished material shall be perfect in all its parts, must be free from injurious seams, ragged edges, flaws or cracks, and must have a clean, smooth finish. Finished material.

111. The tensile strength, limit of elasticity and ductility are to be determined from standard test pieces, not less than  $\frac{3}{8}$  of an inch in thickness, nor less than 12 inches long and cut from the finished material. Test pieces.

112. Tests to determine elongation shall be made on a length of eight inches. Elongation.

113. All sample or full-size pieces shall be tough and ductile, incapable of tempering, and must show uniform fractures, fine grained, of a blue-grey color, without fiery lustre or blackish cast. Fractures.

114. The ultimate tensile strength for all steel except that used for rivets and adjustable members shall be 64,000 pounds per square inch. Steel for rivets and adjustable members shall have an ultimate tensile strength of 57,000 pounds per square inch. Test bars must show an average tensile strength within 4,000 pounds per square inch of that specified. Tensile strength.

115. Medium, soft and rivet steel shall have an elastic limit of not less than one-half the ultimate strength. In 8 inches medium steel shall have a minimum elongation of 22 per cent.; soft steel, 25 per cent.; medium steel for pins, 20 per cent. Elastic limit.

116. Specimens of medium steel when heated to a cherry red and cooled in water at 70 degrees Fahrenheit shall be capable of bending 180 degrees around a circle whose diameter is equal to the thickness of the test piece, without showing signs of cracking on the convex side of the bend. Specimens of rivet and soft steel shall be capable of bending cold 180 degrees and closing down flat upon themselves without cracking. Bending tests.

117. Punched rivet holes in medium steel, pitched two diameters from a sheared or rolled edge must stand drifting until their diameters are 50 per cent. greater than those of the original holes without signs of cracking the metal. Drifting test.

118. No reliance shall be placed upon the welding of steel. Welding steel.

119. Medium steel may be used in compression in chords, pedestals and posts without reaming punched holes for all thicknesses of metal that will stand the drifting tests, provided all sheared edges are planed off to a depth of  $\frac{1}{8}$  inch. Medium steel in compression.

120. In all other cases medium steel over  $\frac{5}{8}$  inch thick must have all sheared edges planed off to a depth of  $\frac{1}{8}$  inch, and all Shearing and reaming.

holes drilled or reamed to a diameter  $\frac{1}{8}$  inch larger than the punched holes, so as to remove all the sheared surface of the metal.

Soft steel.

121. Soft steel which satisfies the drifting test need not be reamed.

Variation in weight.

122. Variation of  $2\frac{1}{2}$  per cent. from the specified weight or dimensions of material may be cause for rejection.

### Castings.

Steel castings.

123. Steel castings shall be made of acid open hearth steel, must be sound and free from blow holes, true to pattern and smooth in finish. Steel castings shall be uniformly annealed.

Ultimate strength.

124. Cast steel shall have an ultimate strength of not less than 67,000 pounds per square inch, an elastic limit of one-half the ultimate, and an elongation in two inches of at least 10 per cent.; test specimens to have a uniform sectional area of  $\frac{1}{2}$  square inch for a minimum distance of two inches.

Iron castings.

125. Iron castings must be of tough grey iron, free from cold shuts or injurious blow holes, true to form and thickness, and of workmanlike finish. Sample pieces, one inch square, cast from the same heavy metal in sand moulds shall sustain a central load of 500 pounds on a clear span of  $4\frac{1}{2}$  feet when tested in the rough bar. A blow from a hammer, on a rectangular edge of the casting, shall produce an indentation without flaking the metal.

### Timber.

Timber.

126. Timber unless otherwise specified shall be first class oak, white pine, red or Norway pine, spruce, tamarac or cedar. It shall be sawn true and out of wind, free from wind shakes, large or loose knots, decayed or sap wood, worm holes or other defects impairing its strength or durability.

### Painting.

Scale and rust.

127. All metal before leaving the shops must have loose scale and rust thoroughly removed, and be given a good coat of pure raw linseed oil, which must be worked into all joints and open spaces.

Surfaces in contact.

128. Surfaces in contact with one another shall each be painted before being riveted together.

Surfaces not accessible.

129. All surfaces that will not be accessible after erection shall receive two coats of paint, the metal to be perfectly cleaned before painting.

Planed or turned surfaces.

130. All planed or turned surfaces must be coated with white lead mixed with tallow before shipment.

Painting after erection.

131. After erection all rust spots shall be carefully cleaned, and the metal work shall be thoroughly and evenly painted with two additional coats of paint of different colors. Recesses which might retain water or through which water could enter, must be filled with thick paint or waterproof cement before the final coat of paint is applied.

132. Unless otherwise specified, the paint to be used shall consist of red lead, lamp-black and pure raw linseed oil. These shall be mixed in the proportions of one pound of lamp-black, eight pounds of red lead and one gallon of linseed oil. The red lead and lamp-black shall first be mixed dry, the linseed oil added, and the mixture stirred to a uniform consistency. Only a sufficient quantity for immediate use shall be mixed at once. Thinning and drying ingredients shall not be allowed. Quality of paint.

133. Painting shall not be allowed in wet or freezing weather. Weather

### Hand Railings and Foot Walks.

134. Hand railings not less than 3 feet 9 inches in height shall be placed on each side of the superstructure. They shall be strong and durable, of iron pipe or steel lattice, and rigidly braced. Railings shall extend over piers and abutments as specified. Hand railings.

135. The openings in steel lattice railings in the lower half of the fence shall not exceed nine inches square and the bottom rail shall be not more than six inches clear from the felloe guard. Steel lattice.

136. The top flange of railings shall be proportioned to withstand a transverse horizontal thrust of not less than sixty pounds per lineal foot. Top flange.

137. Where footwalks are required they shall, unless otherwise specified, be placed outside the trusses and supported on longitudinal beams resting on overhanging steel brackets. Footwalks.

### Concrete Flooring.

138. Unless otherwise specified, the flooring shall be of concrete reinforced with steel. Wheel-guards shall be steel channels or concrete and such as will prevent the hubs of wheels striking any part of the bridge. At each end of all spans over fifty feet, steel expansion aprons shall be used with concrete floors. Ferro-concrete.

139. All necessary material, labor, appliances and implements shall be furnished by the contractor, and shall be such as will secure a satisfactory quality of work. Material and labor.

140. The metal with which the said concrete floor is to be reinforced shall be expanded metal, wire netting, steel bars or other metal approved by the engineer, and is to be completely surrounded by concrete, and it shall be so placed within the concrete and shall be of such tensile strength as to fully provide for the specified loading. Steel reinforcement.

141. Sidewalks shall be 4 inches in minimum thickness and shall be made with a slope of  $\frac{1}{4}$  inch to the foot towards the roadway. The minimum thickness of concrete in the roadway shall be  $4\frac{1}{2}$  inches at the sides and 6 inches at the centre. Thickness of concrete.

142. Down pipes, gratings and other openings or fixtures shall be placed in the walk or roadway wherever required, such openings to be measured continuously as part of the flooring. Down pipes.

143. All temporary framework or staging shall be provided and erected by the contractor to support the concrete flooring while in process of construction, this framework to be firm and substan- Falsework.

tial, of suitable lumber, and in all respects approved by the engineer.

Portland  
cement.

144. All cement employed in the work must be of a favorably known brand of Canadian Portland cement, and approved by the engineer. It shall be delivered in barrels or equally tight receptacles, and after delivery must be protected from the weather by storing in a tight building or by suitable covering. The packages shall not be laid directly on the ground, but shall be placed on boards raised a few inches from it.

Mixing  
concrete.

145. The concrete shall be composed of gravel and Portland cement, mixed in the proportion of one part by measure of cement to five of fine gravel, no stones of which exceed one and one-half inches in diameter. The concrete shall be mixed on a platform placed close to the work by first spreading evenly a layer of gravel. Upon this shall be spread a proportionate quantity of cement, and the two thoroughly intermixed in a dry state. To this sufficient clean water shall be slowly added, and the whole again thoroughly mixed and brought to the consistency of a stiff mortar.

Wearing  
surface.

146. The sidewalk and roadway shall have a wearing surface one and one-half inches in depth of sand and cement, mixed in the proportion of one part by measure of cement to two parts of sand, the sand to be clean, sharp, of varying sized grain and free from loam, earth or other impurities. The sand and cement shall be first mixed in a dry state, then sufficient water shall be added to properly moisten, and the whole shall again be thoroughly intermixed. This top coating shall be applied to the concrete base before the latter has set, so that a perfect bond between the two will be secured. The surface shall be floated and trowelled until smooth and even, and shall be finished with a toothed roller, or as directed by the engineer.

Placing  
concrete.

147. While the work is in progress, it shall be so arranged that a steady supply of mixed concrete will pass from the mixing box to the point where it is to be placed. At any time when the work is interrupted before its completion, or at the end of the day, a wet covering shall be placed over the last layer of concrete, and before the work of depositing the concrete is resumed, this surface shall be thoroughly flushed with water to remove any foreign material which may have gathered thereon, and coated with a thin Portland cement grout. No cement shall be laid in wet or freezing weather.

### Tenders.

Data and  
plans.

148. Contractors submitting tenders shall furnish complete data and plans showing side and end elevations, strain and section sheet, upon which will be given the stresses in the several members, areas required, and sections to be used.

Cost of  
masonry.

149. The cost of masonry and other attendant work shall be considered in comparing the amounts of the several tenders.

Working  
drawings.

150. All working drawings required by the engineer shall be furnished free of cost, and shall be approved by him before work is commenced or material ordered.

Lowest tender.

151. The lowest or any tender shall not necessarily be accepted.

### General Conditions.

152. The contractor shall, free of cost, furnish all facilities and test pieces for the inspection and testing of materials and workmanship. Inspection of the work done shall not relieve the contractor of his obligation to furnish proper material and perform sound and reliable work. Inspection.

153. Unless otherwise specified, the contractor shall furnish all falsework and staging, shall erect and adjust all metal work, and shall put in place all flooring, guards, railings, attachments, etc., complete, to the lines and grades furnished by the engineer. Falsework.

154. The contractor shall at all times carry on the work in such a manner as not to interfere with travel more than is absolutely necessary for the faithful performance of the work, and shall not obstruct any thoroughfare by land and water except by written order of the engineer. Interference with travel.

155. On the completion of the work all surplus or refuse material, falsework, piling or other obstructions shall without unnecessary delay be removed by the contractor. If not removed within forty-eight hours after notice in writing so to do from the engineer, it shall be removed by the engineer at the contractor's expense. Refuse material.

156. The contractor shall during the progress of the work use all proper precautions by good and sufficient barriers, red lights, or watchmen, for the prevention of accident, and he shall indemnify and save the corporation of ..... from all suits and actions and all costs and damages occasioned by the negligence or carelessness of the contractor, or his agents or employees. Prevention of accident.

157. The decision of the engineer shall be final in case of ambiguity of expression of the specifications or doubt as to the correct interpretation thereof. Interpretation of specifications.

158. Any disorderly or incompetent person or persons who may be employed on the work shall be removed when required by the engineer, and no person so removed shall thereafter be employed upon any portion of the work. Disorderly employees.

159. All material used in the work, or any portion thereof, included under this contract, shall be subject to the inspection and approval of the engineer. The supply of each and all material or materials must be so gauged that a sufficient quantity will be kept on hand to allow ample time for testing and examination by the engineer without delay to the work of construction. Inspection of material.

160. All material rejected by the engineer shall be immediately removed from the site of the work by the contractor. In case the contractor should refuse to remove or replace any rejected work or material within forty-eight hours after written notice, such work or material shall be removed by order of the engineer at the contractor's expense. Rejected material.

161. Any defective work or material that may be discovered by the engineer before the final acceptance of the work or before final payment has been made, shall be removed and replaced by work and material which shall conform to the spirit of the specification; failure or neglect on the part of the engineer to condemn Defective work or material.

or reject bad or inferior work or materials shall not be construed to imply an acceptance of such work or materials.

Notices by  
contractor.

162. All necessary notices to waterworks, gas, electric light, telephone or telegraph officials, owners or occupants of property, or other interested parties, shall be given by the contractor.

Payment of  
workmen.

163. The contractor shall punctually pay the workmen employed on the work comprised in these specifications, in cash current, and not what is denominated as "store" pay. And final payment for the work shall not be made until satisfactory vouchers are furnished the engineer by the contractor showing all wages and accounts for materials and implements used in the work to have been paid.

Unforeseen  
loss.

164. All loss arising from unforeseen obstructions or difficulties encountered in the performance of the work under these specifications, or from delay or hindrance from any cause during the prosecution of the same, shall be sustained by the contractor.

Methods and  
appliances.

165. The contractor is to use such methods and appliances for the performance of all the operations connected with the work embraced under this contract as will secure a satisfactory quality of work, and a rate of progress which will secure the completion of the work within the time specified.

Assignment  
of contract.

166. The work to be performed under this contract, or any part thereof, or any money or orders payable under this contract, shall not be assigned nor sub-let by the contractor, without the pre-sanction of the council of the ..... No sub-contractor shall under any circumstances relieve the contractor of his liabilities and obligations under this contract. Should any sub-contractor fail to perform the work undertaken by him in a satisfactory manner, and should this provision be violated, the council of the ..... may, at their option, end and terminate such contract.

Alteration in  
plans and  
specifications.

167. Should any changes or alterations in these specifications or plans in connection therewith be at any time deemed necessary by the engineer, he shall have authority to make such changes or alterations, and, unless otherwise herein provided for, an amount proportionate to the prices contained in the tender upon which the contract was awarded shall be added to or deducted from the original amount of the contract.

Instructions  
to contractor.

168. The contractor or his duly authorized agent or foreman shall at all times while the work is in progress be on the ground, and instruction given by the engineer to such agent or foreman shall be of the same effect as if given to the contractor.

Engineer  
defined.

169. The word engineer, where and whenever used herein, refers to the engineer of ..... or his authorized assistant, or other person appointed by the council of ..... to have charge and oversight of the work.

Contractor  
defined.

170. The word contractor, wherever used herein, refers to the party or parties contracting to perform the work to be done under this contract, or the legal representatives or representative of such party or parties.







